# PROCEEDINGS

OF THE

# NATIONAL ACADEMY OF SCIENCES

Volume 7 NOVEMBER 15, 1921 Number 11

## *THE MOBILITIES OF ELECTRONS*

BY LEONARD B. LOEB*

RYERSON PHYSICAL LABORATORY, UNIVERSITY OF CHICAGO

Communicated by R. A. Millikan, Aug. 17, 1921

In a recent paper[1] it was shown that the electrons could presumably travel through $N_2$ and $H_2$ gases in a free state at atmospheric pressure. It was found in some cases impossible to evaluate the mobilities of these electrons with the low frequencies of commutation available. The values of the mobilities indicated by these results appeared to be so much higher than the values obtained by earlier investigators that it was felt worth while to attempt to measure them accurately.

The mobilities of electrons were accordingly determined in $N_2$ using the high frequency oscillations obtained from two Western Electric Company "E" tube oscillators operating in parallel. The diagram of connections is shown in figure 1. In some cases the oscillations were taken directly from the primary condenser $C_1$, and at other times from the condenser $C_2$ of a secondary circuit tuned to resonance with the primary circuit. The method of measurement was the well known Rutherford alternating current method. The electrons used where photo electrons liberated by ultraviolet light from one of the plates. The ionization chamber used was similar to the one used in measurements of the constant of attachment of electrons to gas molecules,[2] except that still greater precautions were taken in this chamber to avoid contamination. The measurements were made in the same manner as were the measurements for the determination of the coefficient of attachment. The current to the electrometer plate was measured as a function of the value of the alternating potential between the plates. This current was then plotted against the potential difference thus yielding a mobility curve. The potential difference $V_0$, at which this curve cut the axis was substituted in the equation,

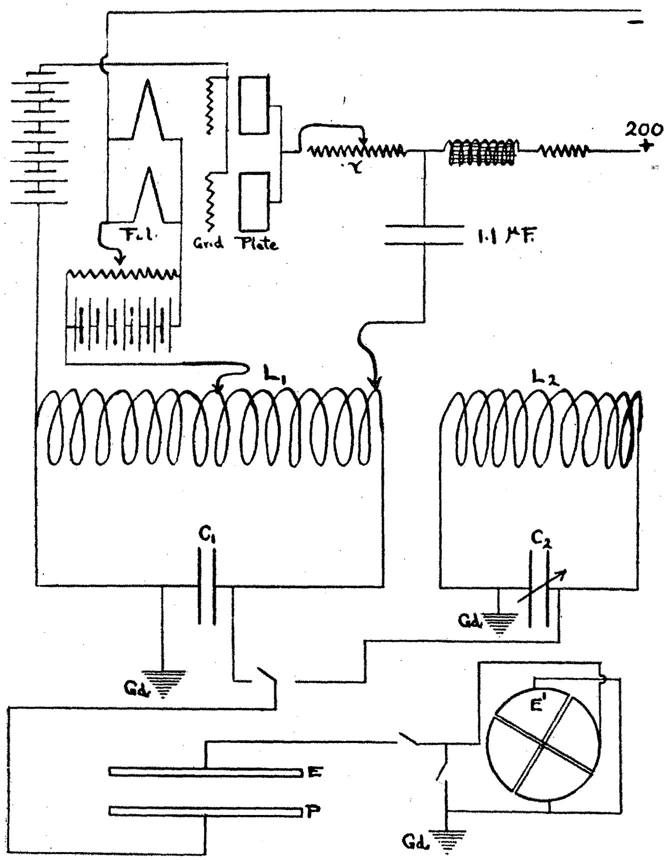


FIG. 1

$$U = \frac{\pi n d^2}{\sqrt{2V_0}},$$

in order to evaluate the mobility $U$. In this equation $n$ is the frequency of the alternations, $d$ is the distance between the plates in cm. and $V_0$ is the voltage in volts as read from the static voltmeter. In the oscillating circuits the potential was varied by varying the resistance $r$ of the plate circuit. Since varying $r$ altered the frequency $n$ slightly the frequency of the oscillations was determined by means of a wave meter for several values of the voltage used in each determination. The experiments reported here covered a range of pressures from 600 mm. to 75 mm. The frequencies used varied from 7000 cycles per second to 150,000 cycles. The voltages used were varied from 10 volts to 300 volts and the plate distances lay between 2.0 cm. and 1.5 cm. The values of $U$ thus obtained were reduced to give the mobility constant $K$ at atmospheric

pressure by means of the equation, $K = (pU)/760$, where $p$ is the pressure in mm. of mercury.

The mobilities found in this manner were astonishingly high. At 600 mm. mobilities of the order of magnitude of 15,000 cm. / sec. were obtained, while the highest previous mobility determined[3] in $N_2$ was 500 cm./sec. Furthermore the value of $K$ obtained was not a constant as one would expect. $K$ was found to be a function of the field strength and pressure. For a given pressure the value of $K$ plotted as a function of $V_0/d$ the field strength was found to lie on a hyperbola of the form, $K = \frac{a}{b + V/d}$. For different pressures a family of such hyperbolae were obtained which were expressed by the equation,

$$K = \frac{571{,}000}{21 + 760\, V_0/(pd)}.$$

This is shown in figure 2. The full curves are drawn from the above equation at values of $p$ and $d$ at which the measurements were made. The

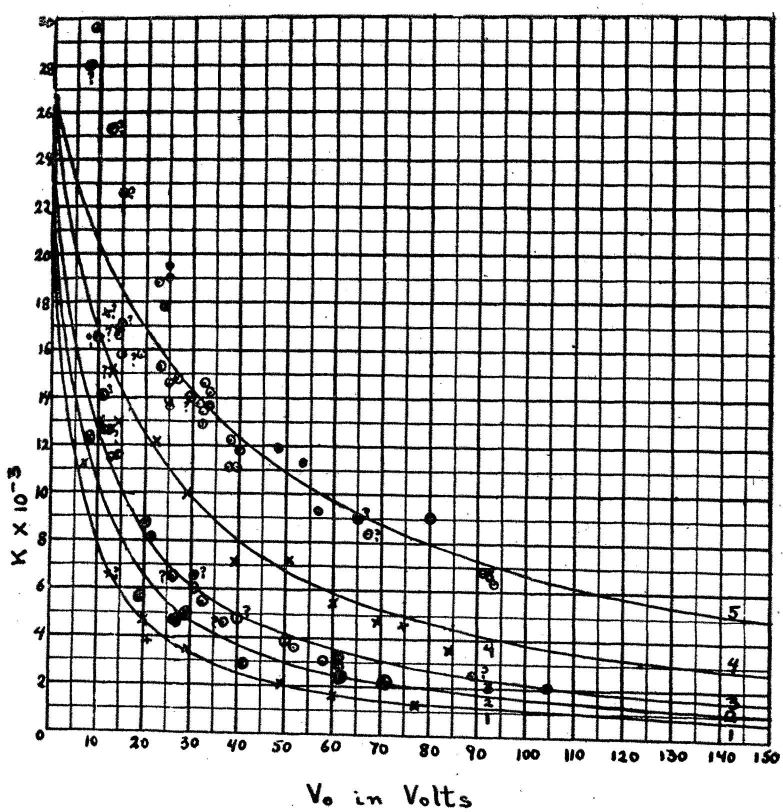


FIG. 2

points plotted are the actual experimental values of $K$ obtained under the conditions of $p$, $V_0$, and $d$ given. When the inaccuracies of such measurements are considered it is seen that the above equation represents the behavior of $K$ to a satisfactory degree of approximation.

The success in measuring mobilities of such high values is probably due to the fact that especial care was taken to avoid contaminating gases, and to the fact that the frequencies employed were very high. The latter factor made it possible to measure the mobilities of purely electronic carriers only, for with the short intervals of time used only electrons which had made no attachments at all could succeed in crossing the plates. It seems likely that the low electronic mobilities observed by the previous workers were found for electrons which had been completely free for only a portion of their path between the plates because of the low frequencies of alternation used. The magnitude of the values obtained in these experiments is more nearly in accord with the values of electron mobilities predicted on the basis of the equations of Townsend[4] and Lenard[5] (i.e. of 6940 cm./sec. and 4260 cm./sec. respectively), than the earlier values.

The fact that $K$ is not a constant is most interesting. It indicates that the term mobility constant has no significance for electrons; since their velocity in the field is no longer directly proportional to the field strength and inversely proportional to the pressure. The way in which $K$ varies with $V_0/d$ and with $p$ indicates that the velocity of drift of the electrons in the direction of the field is influenced by the energy gained by the electron in the electrical field between impacts. A variation of the energy of the electron in the field such as would cause the observed variation of $K$ can only occur when the electrons make *partially elastic* impacts with the gas molecules.

A more detailed account of these experiments will later appear elsewhere. The experiments are being extended to hydrogen and if possible to other gases.

* National Research Fellow of the NATIONAL RESEARCH COUNCIL

[1] Loeb, L. B., these PROCEEDINGS, **6**, 1920 (335).

[2] Loeb, L. B., *Physic. Rev.* (N. S.), **17**, 1921 (94).

[3] Haines, W. B., *Phil. Mag.*, **30**, 1915 (503).

[4] Townsend, J. S., *Electricity in Gases*, Oxford, 1914 (174 ff); also *Phil. Mag.*, **40**, 1920.

[5] Lenard, P., *Ann. Physik*, **40**, 1913 (409).